The life history and ecology of the Pink-tailed Worm-lizard *Aprasia parapulchella* Kluge – a review

David T.Y. Wong[1], Sandie R. Jones[2], William S. Osborne[1], Geoff W. Brown[3], Peter Robertson[4], Damian R. Michael[5] and Geoffrey M. Kay[5]

[1] Institute for Applied Ecology, Building 3, University of Canberra, ACT 2601.
Email: David.Wong@canberra.edu.au; Will.Osborne@canberra.edu.au

[2] Office of environment and Heritage, PO Box 733, Queanbeyan NSW 2620
Email: sandie.jones@environment.nsw.gov.au

[3] Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, PO Box 137, Heidelberg, VIC 3084. Email: Geoff.Brown@dse.vic.gov.au

[4] Wildlife Profiles Pty Ltd, PO Box 572, Hurstbridge VIC 3099
Email: wildlife.profiles@bigpond.com

[5] Fenner School of Environment and Society, Australian National University, Canberra, ACT 0200.
Email: damian.michael@anu.edu.au; geoffrey.kay@anu.edu.au

ABSTRACT

This review synthesises research on the Pink-tailed Worm-lizard *Aprasia parapulchella* - a threatened species with life-history traits and habitat and dietary preferences that make it particularly vulnerable to decline. Further information on the ecology of *A. parapulchella* is required in order to develop effective approaches to conservation and management, particularly given the conservation status of the species. *Aprasia parapulchella* is a dietary specialist living in the burrows of small ants, the eggs and larvae of which it preys upon. It is late maturing (adult size probably attained in the third or fourth year of life), has a small clutch, is thought to be long-lived and has specific habitat preferences. It has a strong association with landscapes that are characterised by outcroppings of lightly-embedded surface rocks. The lizard is associated with a particular suite of ant species and ground cover tending towards open native vegetation (grasses and shrubs) at most sites, but with regional differences. Although the highest densities have been recorded in areas without tree cover, the species has also been found in open-forest and woodland. The relative density of populations and the snout-vent length and weight of specimens reveal regional differences, suggesting that further analysis of the genetic status of the population across its range is warranted. There is still much to learn about the ecology of the species, in particular with respect to movement, breeding, dispersal and the relationship between lizards and ants. Further survey for new populations remains a key priority.

Key words: *Aprasia parapulchella,* Australia, Pink-tailed Worm-lizard, Pygopodidae, threatened species, reptile, grassland, woodland.

Introduction

The genus *Aprasia* (Pygopodidae) is a geographically dispersed and highly fragmented group with small populations distributed mostly in mesic-temperate areas of Australia that receive high winter rainfall (Jennings *et al.* 2003). The Pink-tailed Worm-lizard *Aprasia parapulchella* is the most south-easterly occurring species of the genus and is distributed along the western foothills of the Great Dividing Range between Bendigo in Victoria and Gunnedah in northern New South Wales (NSW) (Figure 3). It is an intriguing species by virtue of its distinctive morphology, fossorial habits and unusual life-history, which involves co-habitation in the burrows of ants whose eggs and larvae it preys on. Its life-history traits (late-maturing, low reproductive rate, likely low vagility) and specific habitat and dietary requirements make it sensitive to landscape change (Purvis *et al.* 2000; Davies *et al.* 2004). Known and potential threats to the species include pasture improvement, overgrazing, soil disturbance, rock removal, weed invasion, inappropriate fire regimes and fire management activities, recreational activities and predation. The species is listed as threatened in each state in which it occurs as well as nationally. It has been assigned 'vulnerable' status nationally *(Environment Protection and Biodiversity Conservation Act* 1999), in the Australian Capital Territory (ACT) *(Nature Conservation Act* 1980*)* and in NSW *(Threatened Species Conservation Act* 1995*)* and 'endangered' status in Victoria *(Flora and Fauna Guarantee Act* 1988). Therefore, a comprehensive understanding of the life history, ecology and distribution of the species is essential for future conservation efforts.

There have been several investigations into the distribution, ecology and conservation of *A. parapulchella* since its description. However, almost all of this information is contained in technical reports or theses and is not readily accessible. It is critical that this information be made more widely available and that knowledge gaps are identified. Therefore, the aim of this review is to synthesise available biological and ecological information and identify areas for future research.

Taxonomy and morphology

Aprasia parapulchella (Figure 1; Figure 2), one of the 12 species in the genus, belongs to the family Pygopodidae (flap-footed lizards) (Wilson and Swan 2008). *A. parapulchella* was described by Kluge in 1974 from 20 specimens collected at Coppins Crossing (the type locality) in the ACT and one specimen from Tarcutta, NSW (Osborne *et al.* 1991).

A. parapulchella has a slender body with a blunt head and rounded tail. Adults may reach a maximum snout to vent length (SVL) of approximately 150 mm and may reach a total length of about 240 mm (Jones 1999). Its head and nape are dark brown to black (often having a mottled appearance on closer inspection) merging to slate grey, grey brown or coppery brown on the body. Dark dots or longitudinal bars on the centre of each dorsal scale give the appearance of faint longitudinal lines running down the body and tail. The tail, the worm-lizard's most distinctive feature, is nearly as long as the body and becomes pinkish- or reddish-brown in colour posterior to the vent. The ventral surface is whitish and shiny with the pinkness of the tail more evident on this surface. The species displays smooth body and ventral scales with a scale-count of 14 rows (including ventrals) at mid-body (Cogger 1992). Three enlarged pre-anal scales are evident (Cogger 1992) and cloacal spurs protrude from under the hind-limb flaps in adult males, allowing for sex determination (Jones 1999). The sex of adults may also be determined by running a dissecting needle along the upper maxillary surface (upper surface of the jaw), with males possessing a rough maxillary surface. However, this method is more invasive than checking for cloacal spurs and is not the preferred method for determining gender (Jones 1992; Jones 1999).

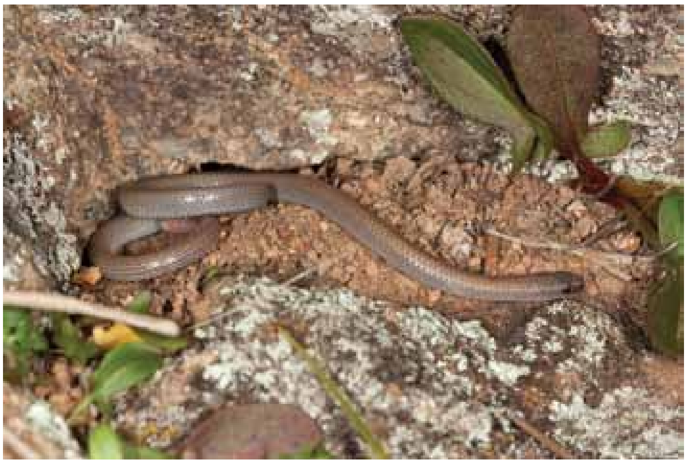

Figure 1. Adult *A. parapulchella.* found within the Murrumbidgee River Corridor. Photo: David Wong.

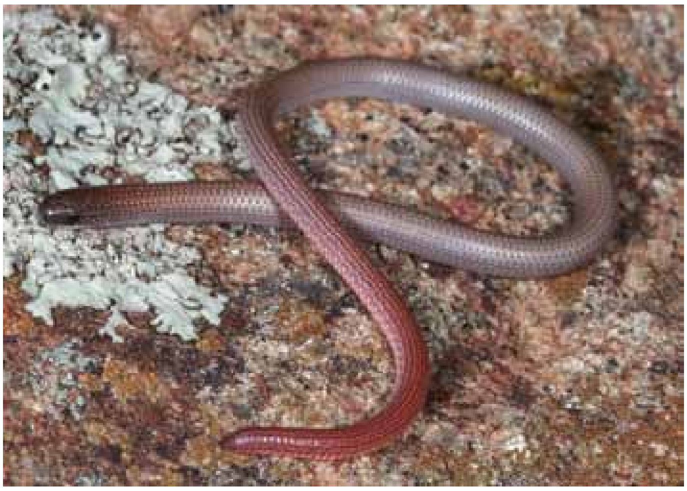

Figure 2. Juvenile *A. parapulchella.* Note pink tail and longitudinal broken lines along the body. The head pattern appears to be unique between individuals. This may offer the potential for individual identification based on head pattern. Photo: David Wong.

Aprasia parapulchella can be separated from all other species of *Aprasia* in eastern Australia by the following combination of characters: (1) the first upper labial scale is wholly fused with the nasal scale, (2) three pre-anal scales are present, (3) two pre-ocular scales are usually present, and (4) there is an absence of a lateral head pattern (Cogger 1992; Wilson and Swan 2008).

Biology and ecology

The biology and ecology of *A. parapulchella* have been studied to varying degrees. Most information is available on the lizard's distribution, habitat, diet and the types of ants it is associated with. Less well known, is the species' population ecology, including reproductive behaviour and activity patterns, as well as the specific nature of interactions between *A. parapulchella* individuals and the species and the ants with which they share burrows. A summary of the current knowledge of the biology and ecology of the species is outlined below.

Distribution

A. parapulchella was originally thought only to occur within or close to the ACT and at single sites near Tarcutta and Cootamundra in NSW (Jenkins and Bartell 1980; Osborne *et al.* 1991). With increasing interest in the species, many new locations have been reported (Figure 3). We now know that *A. parapulchella* is patchily distributed along the foothills of the western slopes of the Great Dividing Range between Bendigo in Victoria and Gunnedah in NSW. Populations across the range of the species are fragmented, with known populations in Victoria centred on Bendigo and known sites in NSW highly isolated from each other. The species occurs at elevations ranging from 180m ASL at Whipstick, north of Bendigo, to 815m ASL at Mount Taylor, ACT.

The distribution of the species is best known in the ACT (Figure 4) where there has been considerable localised survey effort. Here, *A. parapulchella* is mainly distributed along the Murrumbidgee and Molonglo River corridors

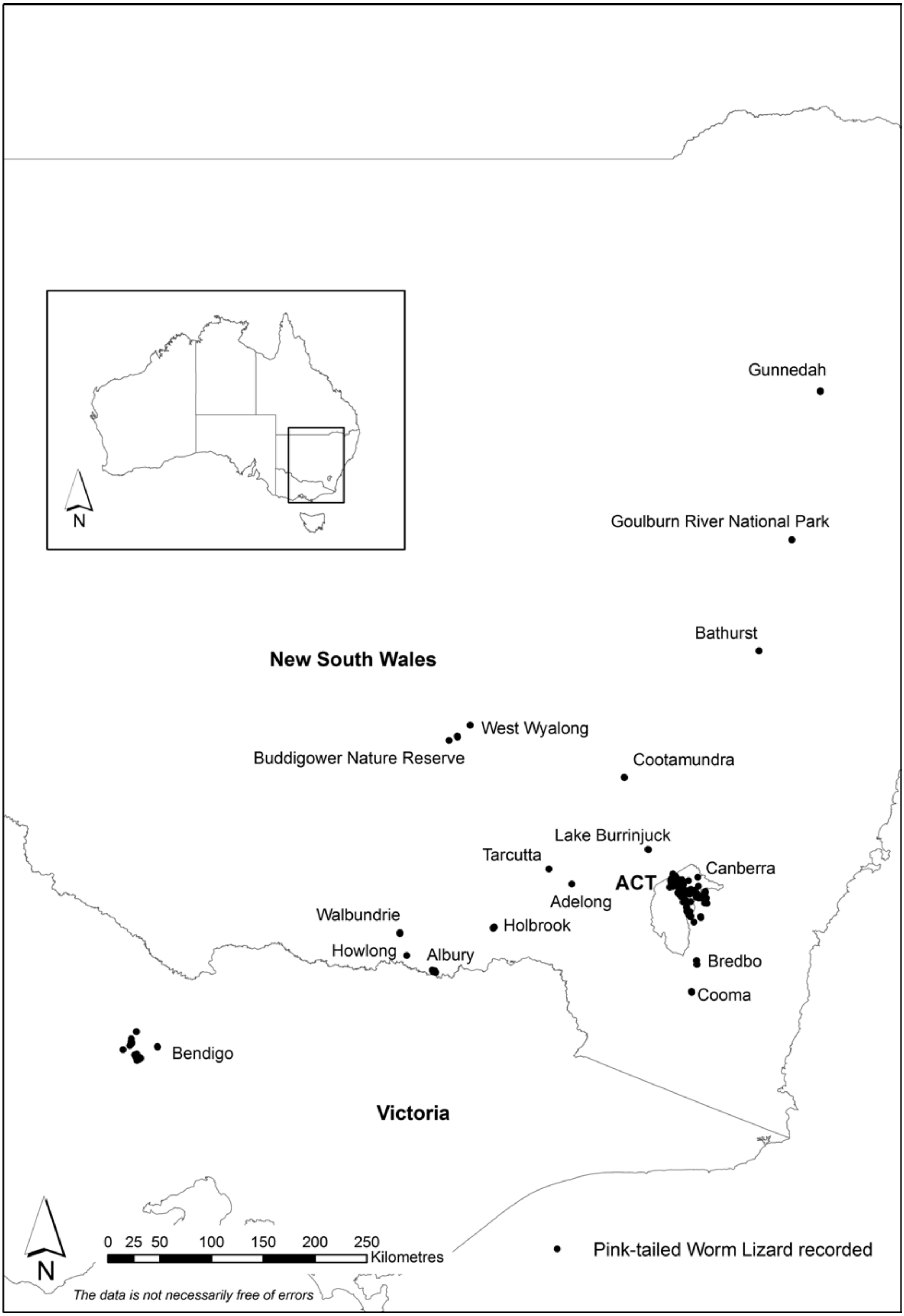
N
Gunnedah
Goulburn River National Park
Bathurst
New South Wales
West Wyalong
Buddigower Nature Reserve
Cootamundra
Lake Burrinjuck
Tarcutta
ACT
Canberra
Adelong
Walbundrie
Holbrook
Howlong
Albury
Bredbo
Cooma
Bendigo
Victoria
0 25 50 100 150 200 250 Kilometres
N
● Pink-tailed Worm Lizard recorded
The data is not necessarily free of errors

Figure 3. Known distribution of *A. parapulchella* in Australia.

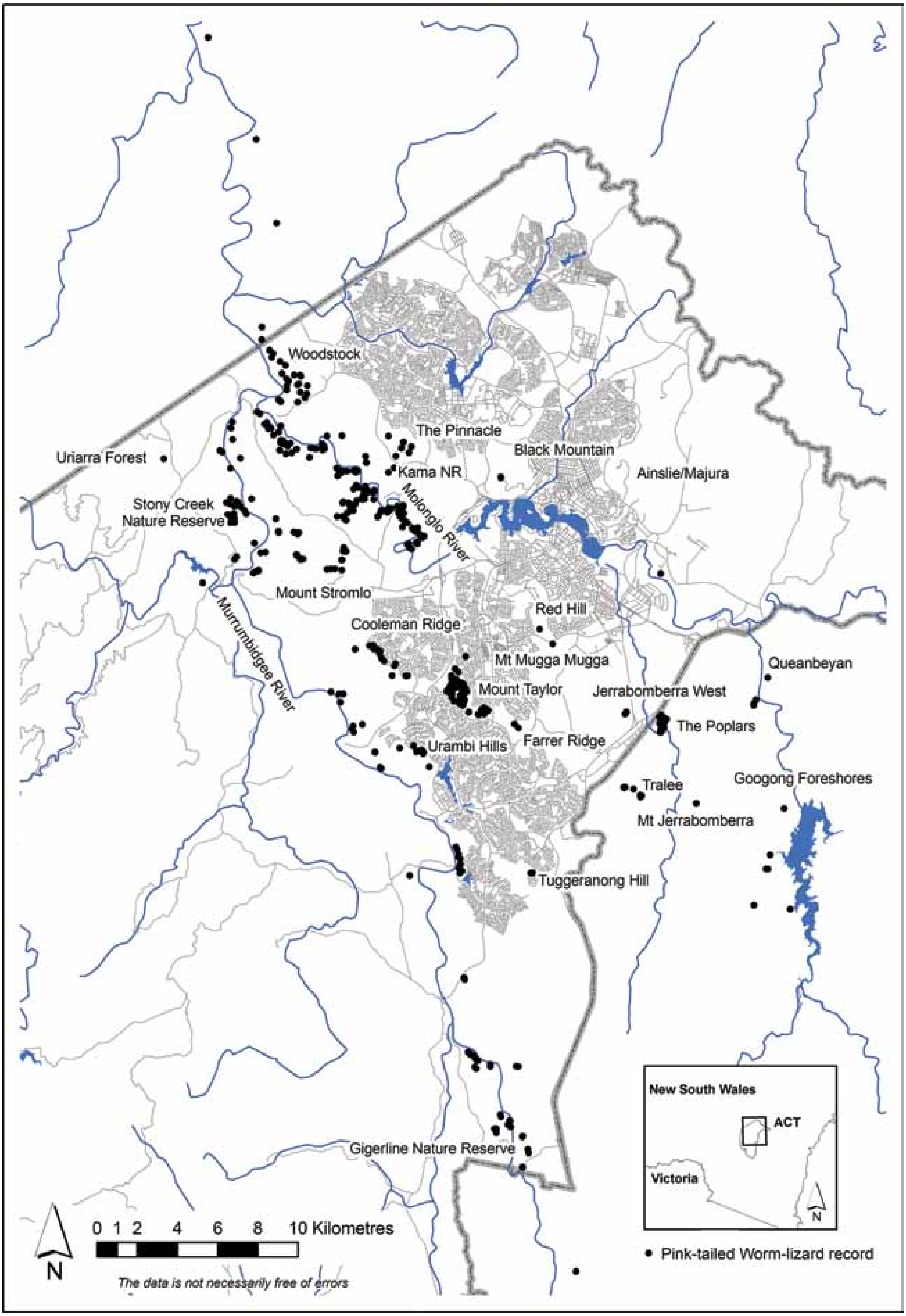
Woodstock
The Pinnacle
Black Mountain
Uriarra Forest
Kama NR
Ainslie/Majura
Stony Creek Nature Reserve
Molonglo River
Mount Stromlo
Murrumbidgee River
Red Hill
Cooleman Ridge
Mt Mugga Mugga
Queanbeyan
Mount Taylor
Jerrabomberra West
The Poplars
Farrer Ridge
Urambi Hills
Tralee
Googong Foreshores
Mt Jerrabomberra
Tuggeranong Hill
Gigerline Nature Reserve
New South Wales
ACT
Victoria
N
0 1 2 4 6 8 10 Kilometres
N
● Pink-tailed Worm-lizard record
The data is not necessarily free of errors

Figure 4. Known distribution of *A. parapulchella* in the ACT.

and surrounding areas as well as on some of the hills found within Canberra Nature Park (Osborne *et al.* 1991; Osborne and McKergow 1993). Although widespread, the population in the ACT is patchily distributed with occurrences restricted to rocky outcrops within a larger habitat mosaic, although it is not present in all habitats that appear suitable. Osborne and McKergow (1993) surveyed 12 reserves within Canberra Nature Park and detected *A. parapulchella* in six of these: Mount Taylor, Cooleman Ridge, Urambi Hills, The Pinnacle, Farrer Ridge and Mount Arawang. The species is also known from other Canberra Nature Park units including Oakey Hill, McQuoids Hill, Kama Nature Reserve, and Black Mountain (at one location), some areas of leasehold land and some natural remnants within land managed for forestry (ACT Vertebrate Atlas, ACT Parks Conservation and Lands; Osborne and McKergow 1993). There are historical records from within, or close to, the Ainslie-Majura complex, Tuggeranong Hill, and Red Hill (ACT Vertebrate Atlas; Osborne and McKergow 1993) (Figure 4); although Jones (1999) suggested that the species may have been lost from Red Hill.

In NSW, *A. parapulchella* has a widespread, though disjunct distribution, being recorded mostly at isolated sites, including near Tarcutta, Bathurst, Cootamundra, Adelong, Lake Burrinjuck, Yass, Wee Jasper, West Wyalong, Buddigower, Bredbo, Cooma, Queanbeyan, Googong Foreshores, Holbrook, Howlong, Walbundrie (Goombargana Hill), Albury (Nail Can Hill), Goulburn River National Park (Hunter Valley), Mudgee and Gunnedah (Jenkins and Bartell 1980; Osborne *et al.* 1991; Cogger 1992; NSW National Parks and Wildlife Service 1999; Michael and Herring 2005; Sass *et al.* 2008; Ecology Partners Pty Ltd 2009) (Figure 3). Many records are old and have not been the subject of taxonomic scrutiny. Moreover, many of these sites have not been recently surveyed and the extent of the populations (if still extant) at Buddigower, Mudgee, Gunnedah and the Hunter Valley is unknown. Of the NSW sites away from the ACT region, Nail Can Hill Flora and Fauna Reserve and adjoining crown lands near Albury have yielded the most records (Michael and Herring 2005; Michael 2007). *A. parapulchella* was first recorded in Nail Can Hill Flora and Fauna Reserve in August 2002 (Michael 2004), and has subsequently been recorded at seven separate locations there (Michael and Herring 2005; Michael 2007). It is likely that additional populations occur in the state. Recent surveys of Box-Gum Woodland sites in NSW have yielded new records (one between the ACT border and Michelago and one at Lake Burrinjuck).

In Victoria, all records of *A. parapulchella* are located near Bendigo. Robertson and Heard (2008) suggest that range of the populations near Bendigo probably encompasses the Big Hill Range to the south (as yet not recorded at this location), Marong to the west, Kamarooka, approximately 25 km to the north and the Sugarloaf Range, approximately 18 km to the east (Figure 5). Most records are from the Greater Bendigo National Park in the One Tree Hill/Manduring area on the outskirts of Bendigo (approximately 6 km southeast of the CBD) in remnant box-ironbark forest, and the Whipstick area to the north of Bendigo, where there are scattered records for both box-ironbark and mallee vegetation. The remaining records are from Maiden Gully, an outer western suburb of Bendigo approximately 4 km from the CBD (Robertson and Heard 2008).

It is very likely that *A. parapulchella* occurs at other locations in Victoria. Targeted surveys are required to determine if this is the case. Recent habitat assessments and anecdotal reports from north-eastern Victoria suggest the species could potentially occur in the Kiewa Valley (pers. comm. Bridget Doyle), Barnawartha Scenic Reserve and McFarlane's Hill (Dennis Black, La Trobe University pers. comm.) near Wodonga (D. Michael unpubl. data).

Habitat

Geology

In the Canberra region, *A. parapulchella* has been recorded mostly in association with late Silurian acid volcanic geology of the Laidlaw and Hawkins volcanic suites (Osborne *et al.* 1991; Abell *et al.* 2008), although one site on Black Mountain is underlain by quartz sandstone (ACT Vertebrate Atlas, ACT Parks Conservation and Lands). The main rock types associated with the species in the ACT include rhyodacite, rhyolite, dacitic tuff and volcaniclastic sediments, and quartzite at some sites (Osborne *et al.* 1991). At Tarcutta, a population of *A. parapulchella* has been found under exfoliated boulders of granodiorite. However, searches at a limited number of sites in areas of outcropping granodiorite, leucogranite and Ordovician sediments in the ACT were unsuccessful in detecting the species (Osborne *et al.* 1991). More extensive targeted surveys are required to examine this ostensible relationship.

In the Albury area, *A. parapulchella* sites are characterised by shallowly embedded surface rock and intrusive porphyritic granite outcrops; here, lizards have only been found under small (less than 300 mm wide and 50 mm deep) surface rocks composed of granitised schist resulting from contact metamorphism with gneissic intrusions (Michael and Herring 2005). The Holbrook and Goombargana Hill site near Walbundrie are characterized by granitoids (Michael *et al.* 2008), whereas the Howlong site is characterised by metasedimentary surface rocks. Interestingly, most of the surface rocks present at Howlong were exposed after the soil was deep ripped in preparation for revegetation works 15 years ago (D. Michael pers. obs.). Lizards have been found under metasediments at Howlong (D. Michael pers. obs.) and near Bathurst and Bendigo (Jones 1999). Records from Buddigower and Gunnedah appear to be associated with laterite (J. Caughley, formerly with NSW National Parks and Wildlife Service and D. Coote pers. comm.).

Records in the Bendigo area appear to coincide with Palaeozoic metasediments of the Castlemaine supergroup. Paleozoic metasediments are the oldest geology type in the area and form moderately to highly weathered subdued hills (Kotsonis and Joyce 2003).

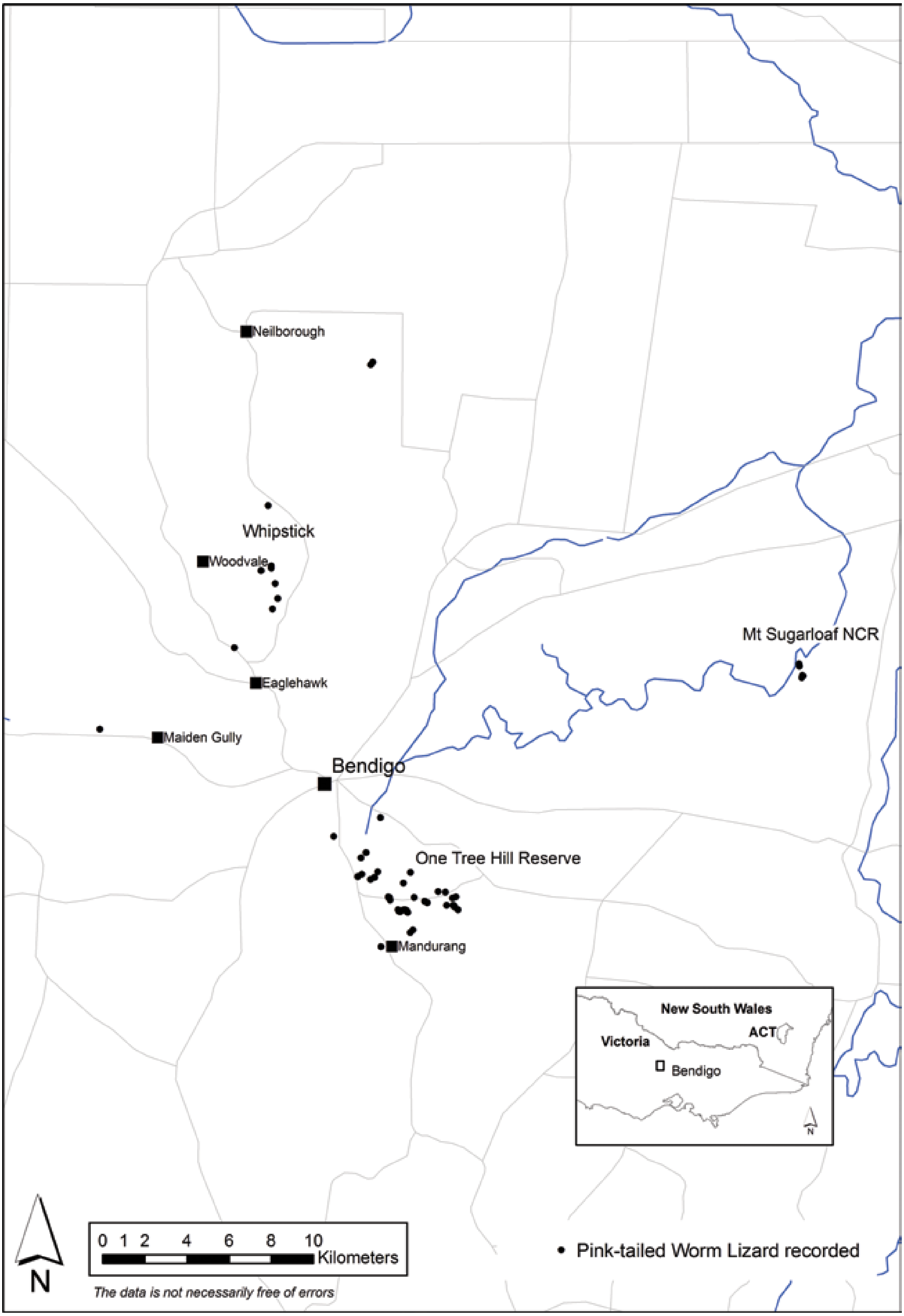
Neilborough
Whipstick
Woodvale
Eaglehawk
Maiden Gully
Bendigo
One Tree Hill Reserve
Mandurang
Mt Sugarloaf NCR
New South Wales
ACT
Victoria
Bendigo
N
0 1 2 4 6 8 10
Kilometers
N
The data is not necessarily free of errors
• Pink-tailed Worm Lizard recorded

Figure 5. Known distribution of *A. parapulchella* in Victoria.

Soils

Soils at most of the sites in the ACT are derived from mid- to late-Silurian acid to intermediate volcanics and are made up of shallow, rocky, friable sandy-loams showing little differentiation of horizons with the exception of a slight accumulation of organic matter at the surface (Osborne and McKergow 1993). Records in the Whipstick area appear to coincide with stony to gravelly loam, red sodic and yellow sodic duplex soils (Mikhail 1976). Because of the geographical separation of the NSW sites and lack of readily available information, information on soils at NSW sites is not covered in this review. Further investigation is warranted in this area.

Aspect and slope

No significant relationship between the presence of *A. parapulchella* and aspect is apparent (Osborne *et al.* 1991; Jones 1992; Roberson and Heard 2008). Most surveys in the ACT have tended to avoid southerly aspects, presumably because lizards are more likely to be recorded at sites receiving higher levels of solar radiation (Jones 1992). Jones (1992) recorded more individuals on north-easterly and south-westerly aspects, although south-easterly and easterly aspects were under-represented in the study.

Lizards have been found on slopes ranging from 3° to 26° in the ACT, with most recorded on slopes between 10° and 14° (Osborne *et al.* 1991; Jones 1992). In Albury, lizards have been recorded on northerly, westerly and south-westerly aspects and on slopes ranging from 9 ° to 14 ° (Michael and Herring 2005). Surveys at One Tree Hill in Bendigo found lizards at sites with slopes in the range of 5 ° - 40 ° (n = 41, mean = 13.4 °, SE = 0.87) with the majority of records occurring on slopes of 5 ° – 25 ° (Brown 2009). Robertson and Heard (2008) recorded *A. parapulchella* on the mid and upper slopes of low hilly terrain (less than 350 m ASL) in Victoria but not on lower undulating country or from the slopes of the major range (above 350 m ASL).

Vegetation

A. parapulchella generally occupies sites with a grassy ground layer with little or no leaf litter, and relatively low tree and shrub cover (Osborne *et al.* 1991; Osborne and McKergow 1993; Michael and Herring 2005; Robertson and Heard 2008). In Victoria, tree canopy cover has not been found to influence the occurrence of the species. However, the cover of bare ground was found to be higher and the cover of leaf litter lower, at sites with *A. parapulchella* compared with randomly-selected sites. The cover of shrubs and ground layer vegetation are slightly higher than at random sites compared with those where the species is recorded (Robertson and Heard 2008).

In the ACT, *A. parapulchella* tends to be more abundant at sites where native grass species dominate, especially Kangaroo Grass *Themeda triandra* (Jones 1999; Osborne *et al.* 1991; Osborne and McKergow 1993). Brown (2009) recorded generally low densities of *A. parapulchella* in the Bendigo area with the exception of one site at One Tree Hill, where the cover of grass tussocks and herbs/forbs was notably higher than at the other sites surveyed. Sites with *A. parapulchella* may contain exotic annual species, suggesting that the species can occur at sites with some level of disturbance to the ground layer vegetation. A spring flush of exotic annual grasses is a common occurrence in many communities dominated by native grasses, perhaps due to historical grazing and associated nutrient addition (Pettit *et al.* 1995). However, the species is unlikely to be found at site where the ground layer vegetation indicates very high levels of modification (e.g. highly pasture improved sites or stock camps) (Jones 1999; Michael and Herring 2005; Osborne and McKergow 1993). Jones (1999) found that *A. parapulchella* was more likely to be present at sites dominated by thick-cover forming grasses such as Kangaroo Grass. This may be due to a lower level of historical grazing at the sites where tall, thick-cover forming species dominate (McIntyre and Tongway 2005). At some sites the occurrence of *A. parapulchella* is negatively associated with cover abundance of woody species and rosette herbs (usually exotic species such as Flatweed *Hypochearis radicata*) (Jones 1999), lending support to the hypothesis that the lizard prefers habitat without a dense cover of trees or shrubs and that the abundance of weed species may also influence its occurrence. Figure 6 shows an example of typical suitable habitat for *A. parapulchella* in the ACT.

In the ACT, *A. parapulchella* has mostly been found in areas of secondary grassland with sparse or no tree cover and a moderate to extensive cover of native grasses (Jones 1992). The critically endangered White Box *Eucalyptus albens* - Yellow Box *E. melliodora* - Blakely's Red Gum *E. blakelyi* Grassy Woodland and Derived Native Grassland community *(Environment Protection and*

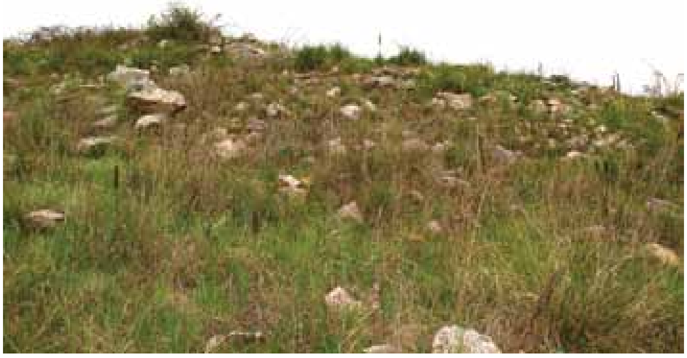

Figure 6. Typical high quality habitat suitable for *A. parapulchella* located at the type locality (Coppins Crossing, ACT). There is a high cover of lightly embedded surface rock. The ground layer vegetation is relatively intact with Kangaroo Grass *Themeda triandra* present. Other forbs such as Creamy Candles *Stackhousia monogyna* and sedges, *Lomandra spp.* can be made out. Note, this site does exhibit some weed invasion from Blackberry *Rubus fruticosus* and Mullein *Verbascum* species. Photo: David Wong.

Biodiversity Conservation Act 1999) is often associated with such sites. *E. albens* is absent from this community in the ACT. Other tree species found at sites include Red Box *E. polyanthemos*, Red Stringybark *E. macrorhyncha*, Brittle Gum *E. mannifera*, Scribbly Gum *E. rossii* and Drooping Sheoak *Allocasuarina verticillata* (Osborne et al. 1991; Barrer 1992; Osborne and McKergow 1993; Jones 1999). *A. parapulchella* has also occasionally been found in Burgan *Kunzea ericoides* shrubland, woodland or open forest (e.g. Black Mountain); usually in more open areas (Barrer 1992; Osborne and McKergow 1993; D. Wong pers. obs.). Shrub species found at sites occupied by *A. parapulchella* may include Burgan *Kunzea ericoides*, Blackthorn *Bursaria spinosa* subsp. *lasiophylla*, *Cassinia* spp., Juniper Grevillea *Grevillea juniperina*, Urn Heath *Melichrus urceolatus* and Daphne Heath *Brachyloma daphnoides* (Osborne *et al.* 1991). Dominant grass species include Kangaroo Grass, Red Grass *Bothriochloa macra* and Speargrasses *Austrostipa scabra* subsp. *falcata* and *Austrostipa bigeniculata*. Discriminant functional analysis revealed the abundance of Squirrel Tail Fescue *Vulpia bromoides*, Wild Oats *Avena fatua*, Red Grass *Bothriochloa macra*, Delicate Hairgrass *Aira elegantissima* and Wattle Mat-rush *Lomandra filiformis* to be associated with *A. parapulchella* sites (Jones 1999); Sheep's Burr *Acaena ovina* and Tall Speargrass *A. bigeniculata* were associated with sites where the species was not recorded. Kangaroo Grass has also been found to be an important species for *A. parapulchella*, especially if it occurs as a dominant species (Osborne *et al.* 1991; Osborne and McKergow 1993; Jones 1999). The association with the aforementioned exotic species is surprising, but probably due to the fact that many of the sites that were surveyed were in secondary grassland that had undergone some level of grazing in the past and exhibited a degree of weed invasion rather than due to a preference for sites containing those species (Jones 1999).

In NSW, vegetation associations appear to be similar to those in the ACT, with *A. parapulchella* occurring primarily in grassland, secondary grassland, grassy woodlands and, occasionally, open forest. The West Wyalong site is an exception as the vegetation there consists of mallee and broombush and is similar to that found at Whipstick near Bendigo (Jones 1999).

Sites in the Nail Can Hill Flora and Fauna Reserve in Albury support the endangered White Box *E. albens* - Yellow Box *E. melliodora* - Blakely's Red Gum *E. blakelyi* Grassy Woodland and Derived Native Grassland community *(Environment Protection and Biodiversity Conservation Act* 1999). Where sites are located within woodland, Blakely's Red Gum is the dominant species and projective foliage cover is relatively low when compared with some nearby sites (Michael and Herring 2005). A sparse layer of native shrubs may be present, with the ground layer usually comprising Kangaroo Grass and other native grasses and forbs as well as introduced grasses in some areas. At these sites, the lizard has only been recorded in open areas away from canopy cover (Michael and Herring 2005) (Figure 7). One individual was recorded in secondary grassland dominated by exotic pasture grasses and Paterson's Curse *Echium plantagineum* (Michael 2007).

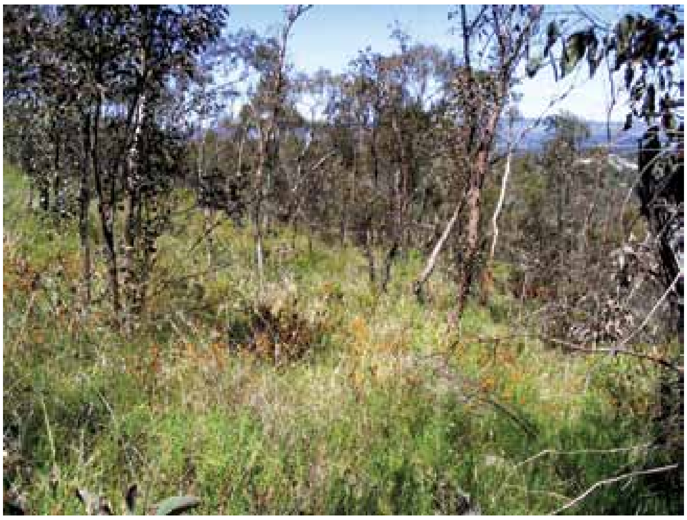

Figure 7. Pink-tailed Worm-lizard habitat at Albury. Photo: Damian Michael.

At the Howlong site, a previously cleared hillside was extensively deep ripped and revegetated with local species of trees and shrubs (Drooping Sheoak, *Acacia* spp., Cypress Pine *Callitris glaucophylla* and White Box) approximately 15 years ago. The site still supports scattered White Box and Blakely's Red Gum trees and the ground cover is dominated by Purple Wiregrass *Aristida ramosa*, exotic annuals and forbs (D. Michael, pers. obs.).

At a single site near Cooma, *A. parapulchella* has been observed on slopes of native grassland and dry forest characterised by many loose and partially embedded rocks. The ground cover is usually dominated by Kangaroo Grass, *Poa sieberiana* and Wallaby Grass *Danthonia* spp. In areas of dry forest, Broad-leaved Peppermint *E. dives* and Candlebark *E. rubida* are the dominant tree species and the understory is dominated by *Cassinia* spp. (R. Rehwinkel pers. comm.).

Sites around Queanbeyan contain native grassland, secondary grassland and open and dry woodland habitats. Kangaroo Grass and Wallaby Grass *Austrodanthonia* spp. typically dominate the ground layer (R. Rehwinkel pers. comm.). Yellow Box and Blakely's Red Gum dominate the canopy in open woodland habitats and Broad-leaved Peppermint *E. dives* and Candlebark *E. rubida* dominate dry forest areas.

At Bredbo and Michelago, *A. parapulchella* has been recorded on slopes of native grassland dominated by Kangaroo Grass, *Poa sieberiana* and Wallaby Grass *Austrodanthonia* spp. (D. Hunter pers. comm.).

Other historical sites at which *A. parapulchella* has been recorded in NSW vary considerably in their dominant vegetation. Mallee vegetation and little or no surface rock characterise the West Wyalong site; the sites at Bathurst and Tarcutta are partially cleared rocky woodlands with the ground-layer dominated by native grasses, although exotic weeds and pasture species are also present (Jones 1999). The Gunnedah site is within White Box, Blakely's Red Gum and Weeping Myall *Acacia pendula* woodland endangered ecological community (*Environment Protection and Biodiversity*

Conservation Act 1999) and the actual site occurs in a natural clearing where lateritic surface rocks are also present. The ground cover is sparse and comprises a mix of exotic and native pasture species and weeds (D. Coote pers. comm.). The vegetation at a site in Holbrook contains a high percentage cover (>70) in the understorey of introduced grass species interspersed with native grass species such as Wallaby Grasses *Austrodanthonia* spp. and Spear Grasses *Austrostipa* spp. (A. Organ, pers. comm.). It is noted, however, that the exotic annual component can vary from year to year.

In Victoria, *A. parapulchella* has been recorded close to Bendigo mostly in relatively open dry sclerophyll forest dominated by Grey Box *E. macrocarpa* and Red Box, with some Red Stringybark *E. macrorhyncha*, Red Ironbark *E. tricarpa* and Yellow Gum *E. leucoxylon* also present. Shrub and ground layer vegetation at these sites is often diverse; Sifton Bush *Cassinia arcuata,* Common Fringe-myrtle *Calytrix tetragona,* Golden Wattle *Acacia pycnantha,* Gold-dust Wattle *A. acinaceae,* Kangaroo Thorn *A. paradoxa* and Cat's Claw Grevillea *Grevillea alpina* are commonly present in the shrub layer. The ground layer vegetation is typically intact with grasses (Spear Grasses *Austrostipa* spp., Kangaroo Grass *themeda triandra,* Red-anthered Wallaby Grass *Joycea pallida*), lilies (*Dianella* spp.) and mat-rushes (*Lomandra* spp.) present (Robertson and Heard 2008).

Sites in the Whipstick area support both box-ironbark and mallee communities. The mallee sites are dominated by Green Mallee *E. viridis,* Blue-leaved Mallee *E. polybractea* and Bull Mallee *E. behriana* with species including Whirrakee Wattle *Acacia williamsonii,* Broombush *Melaleuca uncinata,* Violet Honey-myrtle *M. wilsonii,* Totem Poles *M. decussata* and Scarlet Mint Bush *Prostanthera aspalathoides* present in the understorey. Sites within urban Bendigo are within Mugga Ironbark *E. sideroxylon* woodland with a shrubby understorey dominated by Fabaceae species and open areas dominated by Kangaroo Grass (Jones 1999; Brown 2009). Sites where *A. parapulchella* is present are characterised by a relatively open canopy structure and a high cover of ground layer vegetation (Robertson and Heard 2008). Figure 8 shows a site dominated by Mallee vegetation where *A. parapulchella* was captured in pitfall traps in 1989.

Rocks and home sites

A. parapulchella typically occurs in ant nests under shallowly embedded rocks (Osborne *et al.* 1991; Jones 1999). However, it has also been found at a few sites where rocks are absent, notably in areas of mallee and broombush (e.g. West Wyalong in NSW and at Whipstick State Forest near Bendigo in Victoria) (Jones 1999; Robertson and Heard 2008). The location of shelter sites used by the species in these areas has not been determined. On rare occasions, the species has also been recorded under other substrates such as tin, corrugated iron and old fence posts. In Victoria, *A. parapulchella* occupies sites that contain a higher percentage of rock cover than randomly selected sites, and utilises rocks that are, on average, larger and deeper than randomly-selected rocks (Roberson and Heard 2008). In the ACT, the lizard most frequently utilises rocks with particular dimensions (i.e. 120-220 mm long, 100-150 mm wide, 10-140 mm thick) and is more likely to be found under larger rocks in the winter and summer months, perhaps owing to the greater insulation and heat retention that such rocks would afford (Jones 1999). Rock selection also tends to vary with sex in the ACT, with females more likely to occur under longer and thicker rocks than males (Jones 1999). Rocks occupied by *A. parapulchella* are usually located on soil substrate rather than on rock, grass or litter (Jones 1999; Robertson and Heard 2008; Brown 2009).

Rocks are also an important habitat element for the ants that co-occur with *A. parapulchella*. *A. parapulchella* is a dietary specialist, feeding mainly on the eggs and larvae of small ants (Patchell and Shine 1986; Jones 1992). Ant galleries are important foraging and shelter sites for *A. parapulchella* and provide a thermally stable environment. Figure 9 depicts an *A. parapulchella* specimen and the ant gallery it was found sheltering in. Sloughed skins are sometimes found under rocks (Figure 10).

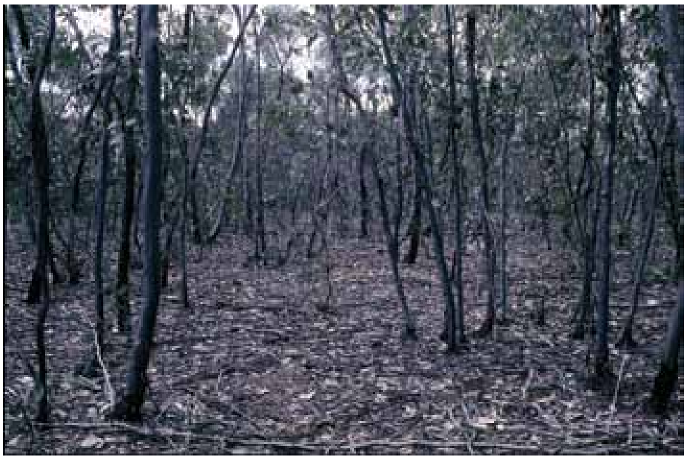

Figure 8. Pink-tailed Worm-lizard habitat in the Whipstick area of the Greater Bendigo National Park. The vegetation at this site is dominated by Mallee species and there is no evidence of surface rock. Photo: Peter Robertson.

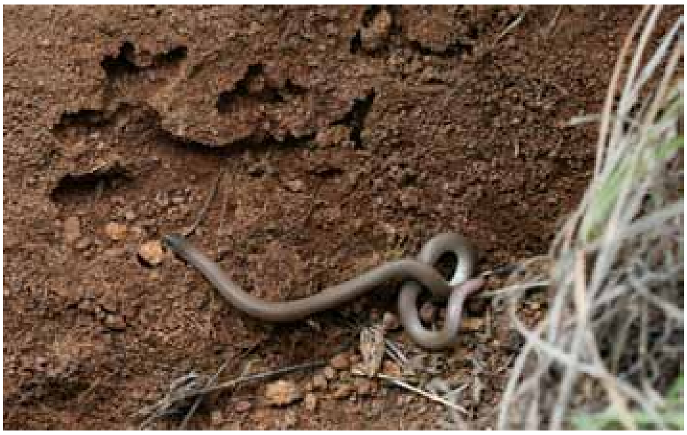

Figure 9. Adult *A. parapulchella* specimen found beneath a rock. The ant galleries that the species utilises are evident in the photo. Photo: David Wong.

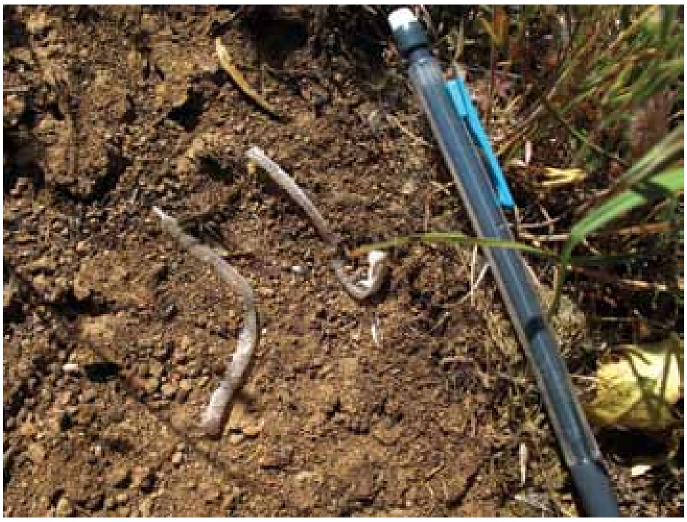

Figure 10. An example of a sloughed *A. parapulchella* skin found underneath a rock. Photo: David Wong.

Population attributes

Differences in the size of specimens measured in the ACT appear to be representative of different annual age classes (Jones 1999) (Table 1). Most specimens in the ACT have a snout-vent length between 100 mm and 130 mm but have been recorded to a maximum snout-vent length (SVL) of 150mm (Osborne and McKergow 1993; Jones 1999). Mean weight and SVL of adults in the ACT and Victoria (Jones 1999; Robertson and Heard 2008; Brown 2009; Wong 2008 and 2009 unpublished data) differ substantially (Table 2). Jones (1999) recorded weights ranging between 0.15 g and 2.6 g, whereas individuals in Bendigo weighed between 0.1 g and 4.0 g (Robertson and Heard 2008). Comparing mean SVL and weight for adults in the ACT (Wong and Osborne 2008; 2009, unpublished data) with those in Victoria (Robertson and Heard 2008; Brown 2009) reveals Victorian males and females to be significantly longer and heavier than conspecifics in the ACT (Table 2).

A. parapulchella is reported to have an even sex-ratio (Jones 1999, Robertson and Heard 2008) and displays sexual dimorphism, with females being longer and heavier than males (Jones 1999; Robertson and Heard 2008), probably due to the demands of carrying eggs (Kluge 1974). Ghiselin (1974) suggested that, in species where females are sedentary and sparse, selection may favour relatively smaller males owing to the lower metabolic demands of smaller individuals. Tail length is not significantly different between males and females (Jones 1999; Robertson and Heard 2008; Brown 2009).

The estimation of population size through the use of traditional mark-recapture methods presents difficulties in fossorial reptiles (Henle 1989). A mark-recapture study undertaken at Mount Taylor yielded low recapture rates (6%), yet provided a population estimate of 312 individuals (with upper and lower confidence limits of 599 and 145) (Jones 1999). A 1992 survey of a dam site on the Lower Molonglo River yielded a population estimate of 37 individuals after 3000 rocks were turned (Barrer 1992, cited in Jones 1999). This was substantially lower than the population estimate of 157 based on 151 individuals from 40 000 rocks subsequently turned at the same site during the complete removal of all stones (Jones 1999). Such disparities underscore the risk of relying on single sampling events.

Table 1. Mean and range of snout-vent lengths for different age-classes of *A. parapulchella* in the ACT (adapted from Jones 1999).

Age-class	Sex	Mean Snout-vent length (mm)	Snout-vent length range (mm)
First year Juvenile	Indeterminate	60	52 – 68
Second year Juvenile	Indeterminate	80	68 – 90
Third year	Indeterminate	96	87 – 110
> Third year Adult	Male	109	85 – 134
> Third year Adult	Female	120	90 – 148

Table 2. Comparison of mean snout-vent length and mean weight of male and female *A. parapulchella.* specimens captured in the ACT and Victoria and results of t-tests.

Sex	Attribute	**ACT** (Wong and Osborne 2008 and 2009, unpublished data)	**Victoria** (Robertson and Heard 2008; Brown 2009)	**t**	**DF**	**p**	**SE**
Male	SVL (mm)	104.06 (N = 83 SE = 1.788)	119.9 (N= 22 SE= 1.58)	- 6.663	76	<0.001	3.576
	Weight (g)	1.15 (N = 52 SE = 0.062)	1.69 (N = 22 SE = 0.062)	- 5.170	72	<0.001	0.104
Female	SVL (mm)	114.97 (N = 86 SE = 1.611)	129.35 (N = 20 SE = 3.545)	- 3.834	104	<0.001	3.751
	Weight (g)	1.38 (N = 56 SE = 0.621)	2.00 (N = 20 SE = 0.129)	- 4.801	74	<0.001	0.129

In the Albury area, the maximum number of individuals recorded during a single survey period was 58 individuals within an area of 3.6 ha at one location (along a ridge) and 12 individuals within an area of 1 ha at a second location (Michael and Herring 2005).

A comparison of relative density figures recorded in Victoria (N = 15) and the ACT (N = 57) (Jones 1992; Jones 1999; Robertson and Heard 2008; Brown 1999; Wong 2008 - 2009, unpublished data) reveals mean relative density of *A. parapulchella* estimated at sites where more than 250 rocks were turned to be higher in the ACT (Mean = 5.7 specimens per 1000 stones; N = 57; SD = 3.32) than Bendigo (Mean = 3.5 specimens per 1000 stones; N = 15; SD = 3.44). A t-test performed on log-transformed data revealed a highly significant difference between lizard density at the two locations (t = 3.357; df = 70; p = 0.001).

The differences in density and body size observed in the Victorian and ACT populations are intriguing and warrant further attention. Differences in density may be due to a range of factors. The role of shading in determining thermal conditions is likely to be an important factor and has been found to be important for other reptile species (Michael *et al.* 2008). Unravelling the causes of differences in body size can be difficult as there may be a number of interacting biophysical, physiological and population level factors involved (Dunham *et al.* 1989). However, factors influencing body size at the two locations may include altitude, density of lizards; availability of cover, food and shelter, site availability and the influence of canopy cover on the thermal environment or predation pressure (Ballinger 1979; Dunham *et al.* 1989).

Reproduction

Co-occurrence of individuals beneath stones has been observed in September (G. Kay pers. obs.) and October (Jones 1999) and gravid specimens have been observed in late November and December (Kluge 1974; Jones 1999; Robertson and Heard 2008). Jones (1999) inferred, from data on the smallest individuals observed to be sharing a rock with an individual of the opposite sex, that sexual maturity is probably reached in males at a snout-vent length (SVL) of at least 102 mm (in the third year of life) and in females with an SVL of at least 118 mm (around the fourth year of life). The relatively late maturation in the species suggests that it is relatively long-lived (Jones 1999). While there is no information on oviposition in *A. parapulchella*, it is likely that ant, and perhaps termite, nests are used. This has been documented for other reptiles (Riley *et al.* 1985; De Lisle 1996; Velásquez-Múnera *et al.* 2008). There are no specific records of hatching dates, though hatching is likely to take place in mid- to late summer.

Activity patterns and movement

A. parapulchella mostly lives under rocks and occupies inhabited or uninhabited ant nests (Jones 1999; Osborne *et al.* 1991). Observations of the lizard's activity patterns in the field are limited, due to its cryptic and fossorial nature. Laboratory observations reveal that the lizard is active during the day but not at night time, suggesting a diurnal activity pattern. As well as eating, drinking and moving through grass tussocks in a tank, lizards were observed to sometimes spend days buried under the sandy substrate. Dampening the substrate tended to increase movement around the tank (Jones 1992). In the field, *A. parapulchella* may be more readily detected under rocks shortly after rainfall when there is some moisture in the soil profile (Osborne *et al.* 1991). This may indicate that the lizards move up to the surface from deeper in the ant burrows during these times in particular.

Above-ground daytime activity has been documented for *A. parapulchella* in the field. Such diurnal activity includes basking on a rock or in a tussock close to a rock, moving rapidly through grass and bare ground and traversing a walking track during the warmer spring months (Barrer 1992; Jones 1992; Osborne and McKergow 1993; P. Robertson pers. obs.). Lizards have also been collected on roadsides and in urban areas (R. Bennett pers. comm.). Rauhala (1993) captured eleven *A. parapulchella* in pitfall traps at three sites in the Stony Creek Nature Reserve (located within the Murrumbidgee River Corridor in the ACT) during pitfall trapping undertaken between November and December 1992 and in March 1993. One of these was located in atypical habitat – tall open scrub (*Kunzea ericoides* and *Leptospermum brevipes*) with very little rock or grass cover.

In the ACT, Jones (1999) conducted pitfall trapping (16,536 trap nights) at a single site in rocky habitat occupied by *A. parapulchella* and adjacent non-rocky habitat, between October 1993 and May 1994. Only five specimens of *A. parapulchella* (2% of total captures) were recorded during this study, all during the months of October and november and all in rocky habitat. Robertson and Edwards (1994) observed similar seasonality of movement for the congeneric *A. aurita* with most specimens being trapped in late October, aligned with the mating period. Jones (1999) suggests that the slightly earlier timing of movement for *A. aurita*, compared with *A. parapulchella* may be related to climatic differences.

A recent survey of eleven sites burnt in the 2003 bushfires in the Stromlo Forest area in the ACT (6 sites in former pine plantation; 5 in remnant native woodland or grassland) yielded *A. parapulchella* at two sites previously covered by a mature Monterey Pine *Pinus radiata* plantation. Some specimens were at least 30 m from possible source populations (i.e. rocky habitat areas with remnant native vegetation) and an unexpectedly high density of lizards (6.9 lizards per 1000 rocks turned) was found at one site that had been planted with Monterey Pines eight years prior to the fires (D. Wong and W. Osborne, unpublished data). This finding suggests that the species is able to move across the landscape and occupy new areas to some extent, though the long-term viability of such occupation is not known.

In the ACT, most specimens have been found in spring. Individuals have been found under rocks during the autumn and winter; however, detection is unreliable, when compared with spring detection, and may be dependent on recent rainfall events. Similarly, in the Albury region, with the exception of one record, *A. parapulchella* has only ever been recorded, beneath surface rocks or in funnel traps, between late August and mid November. The one exception was a juvenile recorded beneath a small surface rock in early May 2009 (D. Michael pers. obs.).

Thermoregulation

Field observations (Barrer 1992; Jones 1999; W. Osborne pers. comm.) suggest that *A. parapulchella* primarily uses thigmothermy as a strategy for thermoregulation, drawing heat from the underside of surface rocks (Pough and Gans 1982; Belliure and Carrascal 2002). Thigmothermy, employed by geckos (Garrick 2008), the closest relatives to pygopodids, is a conservative strategy for thermoregulation in reptiles and is often employed by reptiles of smaller body size that are more vulnerable to predation, as this strategy reduces the likelihood of predation (Rummery *et al.* 1995; Garrick 2008). The higher probability of detecting *A. parapulchella* in spring compared to that observed in summer, suggests that surface rocks may play an important role in thermoregulation. The species is rarely found when air temperatures exceed 25°C or during dry summer weather, suggesting that both temperature and moisture regimes may exert an important influence on the activity and location of *A. parapulchella* (Jones 1999). It is likely that the species descends deeper into ant burrows in hotter drier weather, offering one explanation for the difficulty of detection during summer (Jones 1999).

Social behaviour

A. parapulchella sometimes displays gregarious behaviour, with records of aggregations of two to eight individuals (Jones 1999). Jones (1992) found 55 of a sample of 249 individuals to occur in aggregations of between 2 and 5. From a sample of 58 individuals, Michael and Herring (2005) found 28 individuals to be in an aggregation (pairs on eight occasions and aggregations of three on four occasions). Pairs often comprise a male and a female. The fossorial nature of this lizard makes the study of groupings difficult, since additional individuals may be present but not detected when underground.

Relationship with ants

A. parapulchella has been found in association with 15 species of ants (representing 4 to 5 sub-families) and one termite species (Jones 1999). In one study, 75% of *A. parapulchella* captures were recorded under rocks also occupied by ants, whilst 90% of lizards captured were found under rocks where burrows with multiple entrances (characteristic of ant burrows) were present (Jones 1999). This supports findings by Osborne *et al.* (1991), who found 79% of specimens cohabiting with ants and 93% of specimens (N = 46) to be associated with small burrows. Brown (2009) reported ants beneath only 13% of rocks *A. parapulchella* were sheltering beneath near Bendigo, although Robertson and Heard (2008) reported around two-thirds of rocks had ants or ant burrows associated in the Bendigo area. The differences observed could be related to the variable nature of ant activity at the surface. The findings of Jones (1999) suggest that the presence of ants at the surface is affected by season, with significantly fewer *A. parapulchella* found cohabiting with ants in November compared with the months of March, September and October.

Fifty-three percent of specimens recorded by Jones (1999) co-occurred with one species of ant, the Tyrant Ant *Iridomyrmex rufoniger.* This small species aggressively defends its nests when disturbed by intruders (Robinson 1996; Jones 1999). Analysis by Jones (1999) using Ivlev's electivity index (Ivlev 1961) revealed that *A. parapulchella* preferentially selected home sites also occupied by *I. rufoniger*. Electivity analyses of ant sub-families and functional groups also revealed *A. parapulchella* to select home sites occupied by species from the Dolichoderinae sub-family and the Dominant Dolichoderinae functional group.

The mechanism employed by *A. parapulchella* for avoidance of attack by ants is not known, although Jones (1999) speculated that it might be related to the lizard's behaviour or to chemical signals.

Diet

There have been a number of investigations into the diet of pygopodids (e.g. Patchell and Shine 1986; Webb and Shine 1994). Webb and Shine (1994) found that *Aprasia* spp. almost exclusively consumed ant brood, drawing attention to the dietary and morphological convergence between *Aprasia* and typhlopid snakes. Jenkins and Bartell (1980), through the examination of the gut contents of five specimens of *A. parapulchella*, concluded that small ants of the genus *Iridomyrmex* were the most common food item. In a more extensive study using scanning electron microscopy to examine 163 faecal pellets obtained from *A. parapulchella* in the ACT, Jones (1999) found the diet to comprise at least eleven species of ants and two species of termite. Of the ants, *I. rufoniger* was by far the most frequently consumed species, with *Pheidole* spp., *Paratrechina* spp. and *Rhytidoponera metallica* often appearing in the diet. Adult workers of species consumed by *A. parapulchella* ranged in size (1.5 - 4.5 mm long) and more than half of the time were revealed to be co-habiting with *A. parapulchella.* For *I. rufoniger*, this relationship was especially strong, with 77% of *A. parapulchella* cohabiting with *I. rufoniger* found to have consumed the species (Jones 1999). The fact that ant prey taxa were not always the same as those taxa co-habiting with *A. parapulchella* suggests that the lizard forages beyond its immediate environment. A recent study of the diet of the Mallee Worm-lizard *(A. aurita)* and the Pink-nosed Worm-lizard *(A. inaurita)* in north-western Victoria, (Wainer *et al.* in prep.) has revealed similar dietary habits in these species to those observed in *A. parapulchella*. *A. aurita* and *A. inaurita* consumed nine and five species of ants respectively. There was significant overlap in the ant species consumed and a total of only 11 species of ants was recorded in all the scat samples collected from the two lizard taxa, whilst pitfall trapping in the area has recorded a total of 59 species in two sampling years indicating that the species are dietary specialists. The ant species consumed were of similar size to those consumed by *A. parapulchella* (1.5–3.0 mm) and *I. rufoniger* was commonly consumed. The authors also observed that the ant taxa consumed were relatively innocuous species. The species co-occurring with *A. parapulchella* are similar in this respect (J. Wainer, DPI Victoria, pers. comm.).

Jones (1999) found that *A. parapulchella* preferred ant eggs and larvae to adult ants as food, with eggs being preferred over larvae when they were given access to both in captive experiments. Adult ants are only occasionally ingested and this is thought to be due to accidental ingestion of workers tending the brood. This strategy appears to take advantage of a highly nutritious spatially clumped food source. The only non-ant material discovered in lizard scats by Jones (1992) was fungal mycelium, thought to be from a group which exists internally in invertebrates (K. Thomas, University of Canberra, pers. comm.). The findings of Wainer *et al.* (in prep.) indicate similar preferences for brood over adults in *A. aurita* and *A. inaurita*.

Tail loss and predation

The pink-coloured tail of *A. parapulchella* most likely has a role in reducing predation by drawing the attention of predators away from the head and body (Rankin 1976). Therefore, tail-loss may not be a good indicator of predation pressure but rather may indicate escape efficiency or predator inefficiency (Jaksic and Greene 1984; Medel *et al.* 1988). In the ACT tail-loss rates in *A. parapulchella* vary between sites, from 21% to 55% (Osborne and McKergow 1993; Jones 1999). Jones (1999) suggests that the relatively high level of tail loss observed at some sites may reflect an ageing population at those sites, with older individuals more likely to have been exposed to unsuccessful predation attempts (Tinkle and Ballinger 1972; Schoener 1979). However, it is also possible that predation pressure was higher at those sites. No significant sex differences in overall tail loss were reported by Jones (1999).

Research directions

There is still much to learn about *A. parapulchella.* The cryptic behaviour of the species has made it difficult for researchers to address some aspects of its ecology – particularly relating to breeding biology and thermoregulation (Jones 1999). Further information is required with respect to oviposition sites, local movements between rock outcrops, social behaviour and details of the relationship between lizards and ants. Disturbance is thought to be an important correlate in relation to occurrence of the species in agricultural landscapes but the exact mechanisms involved are poorly understood. We also need to increase our knowledge of the species' distribution and habitat requirements. This will require further targeted field surveys, particularly in New South Wales and Victoria. In particular, the extent of the apparent extreme disjunction of the key populations should be examined. The larger body size of individuals collected near Bendigo, when compared to Albury and Canberra is of interest and may reflect underlying genetic differences. Therefore, surveys should be accompanied by genetic studies that address evidence for historical dispersal and consider the effects of fragmentation. Genetic analysis is likely to provide the clearest insights into movement and dispersal in the species at a range of scales, providing estimates of dispersal capability and connectivity and helping to ascertain the influence of major barriers such as roads, urban areas, rivers and highly modified agricultural landscapes. This information is essential for informed conservation planning in relation to *A. parapulchella.*

Acknowledgements

We thank the following people for providing useful information relating to the species: David Hunter, Rainer Rehwinkel and David Coote (Department of Environment Climate Change and Water NSW); Marjo Rauhala, Darren Roso and Peter Beutel (Parks Conservation and Lands, ACT); John Wainer (Department of Primary Industries, Victoria); Dennis Black (La Trobe University); Theresa Knopp (Institute for Applied Ecology, University of Canberra); Aaron Organ (Ecology Partners Pty Ltd); Ross Bennett, Ken Thomas, and Bridget Doyle. Arn Tolsma (Arthur Rylah Institute for Environmental Research, Department of Sustainability and the Environment, Victoria) and Felicity Grant (Parks Conservation and Lands, ACT) kindly helped in the preparation and provision of GIS data for maps and Maria Boyle (University of Canberra) provided statistical advice. Finally, we thank Percy Wong, Sonya Duus and Ingrid Stirnemann, Steven Sass and one anonymous reviewer for useful comments on the manuscript.

References

Abell, R., Brown, C., Finlayson, D., Lenz, S., Mayer, W., McCue, K., McQueen, K., Pillans, B., Rickard, M. and Strusz, D. 2008. *Geology of the Australian Capital Territory*. 1:100 000 scale map. Geological Society of Australia (ACT Division), Canberra.

Ballinger, R. E. 1979. Intraspecific variation in demography and life history of the lizard, *Sceloporus jarrovi*, Along an altitudinal gradient in southeastern Arizona. *Ecology* **60**: 901-909.

Barrer, P. 1992. A survey of *Aprasia parapulchella* along parts of the lower Molonglo River corridor. A report to the ACT Heritage Unit and the ACT Parks and Conservation Service Wildlife Research Unit. Canberra.

Belliure, J. and Carrascal, Luis M. 2002. Influence of heat transmission mode on heating rates and on the selection of patches for heating in a Mediterranean lizard. *Physiological and Biochemical Zoology* **75**: 369-376.

Brown, G. W. 2009. Field surveys for the endangered Pink-tailed Worm Lizard *Aprasia parapulchella* around Bendigo, north-central Victoria. A report to the Goulburn-Broken Catchment Management Authority. Arthur Rylah Institute for Environmental Research, Department of Sustainability and the Environment, Heidelberg, Victoria.

Cogger, H. G. 1992. *Reptiles and Amphibians of Australia, 5th Edition*. Reed Books, Chatswood, Australia.

Davies, K. F., Margules, C. R. and Lawrence, J. F. 2004. A synergistic effect puts rare, specialized species at greater risk of extinction. *Ecology* **85**: 265-271.

De Lisle, H. F. 1996. *The Natural History of Monitor Lizards*. Krieger Publishing Company, Florida.

Dunham, A. E., Grant, B. W. and Overall, K. L. 1989. Interfaces between biophysical and physiological ecology and the population ecology of terrestrial vertebrate ectotherms. *Physiological Zoology* **62**: 335-355.

Ecology Partners Pty Ltd 2009. Hume highway duplication: threatened reptile monitoring 2007/08, New South Wales. Unpublished report for Roads and Traffic Authority. Ecology Parners Pty Ltd, Brunswick, Victoria.

Garrick, D. 2008. Body surface temperature and length in relation to the thermal biology of lizards. *Bioscience Horizons* **1**: 136-142.

Ghiselin, M. T. 1974. *The Economy of Nature and the Evolution of Sex*. University of California Press, Berkeley.

Henle, K. 1989. Ecological segregation in an assemblage of diurnal lizards in arid Australia. PhD Thesis. Australian National University. Canberra.

Ivlev, V. S. 1961. *Experimental Ecology of the Feeding of Fishes*. Yale University Press, Connecticut.

Jaksic, F. M. and Greene, H. W. 1984. Empirical evidence of non-correlation between tail loss frequency and predation intensity on lizards. *Oikos* **42**: 407-411.

Jenkins, R. W. G. and Bartell, R. J. 1980. *A Field Guide to Reptiles of the Australian High Country*. Inkata Press, Melbourne.

Jennings, W. B., Pianka, E. R. and Donnellan, S. 2003. Systematics of the lizard family Pygopodidae with implications for the diversification of Australian temperate biotas. *Systematic Biology* **52**: 757 - 780.

Jones, S. 1992. Habitat relationships, diet and abundance of the endangered Pygopodid, *Aprasia parapulchella* in the Australian Capital Territory and surrounding New South Wales. B. App. Sc. (Honours) Thesis. University of Canberra. Canberra.

Jones, S. R. 1999. Conservation biology of the Pink-tailed Legless Lizard *Aprasia parapulchella*. PhD thesis. PhD thesis. University of Canberra. Canberra.

Kotsonis, A. and Joyce, B. 2003. Regolith mapping at Bendigo, and its relationship to gold in Central Victoria, Australia. In: *Advances in Regolith* (I. C. Roach (ed.)) pp. 239-243. CRC LEME.

McIntyre, S. and Tongway, D. 2005. Grassland structure in native pastures: links to soil surface condition. *Ecological Management & Restoration* **6**: 43-50.

Medel, R. G., Jimenez, J. E., Fox, S. F. and Jaksic, F. M. 1988. Experimental evidence that high population frequencies of lizard tail autotomy indicate inefficient predation. *Oikos* **53**: 321-324.

Michael, D. R. 2004. Distribution, habitat preferences and conservation status of reptiles in the Albury-Wodonga region. *The Victorian Naturalist* **121**: 180-193.

Michael, D. R. 2007. A reptile survey on Nail Can Hill Flora and Fauna Reserve: summary of results. Unpublished report to GHD, Wodonga, Victoria.

Michael, D. R., Cunningham, R. B. and Lindenmayer, D. B. 2008. A forgotten habitat? Granite inselbergs conserve reptile diversity in fragmented agricultural landscapes. *Journal of Applied Ecology* **45**: 1742-1752.

Michael, D. R. and Herring, M. W. 2005. Habitat of the pink-tailed worm lizard *Aprasia parapulchella* in Albury, NSW. *Herpetofauna* **35**: 103 - 111.

Mikhail, E. H. 1976. Soils of the Bendigo District. Soil survey report No. 56. Department of Agriculture, Victoria.

NSW National Parks and Wildlife Service 1999. Recovery Plan for the Pink-tailed Worm Lizard. Draft for public comment. NSW National Parks and Wildlife Service, Hurstville, NSW.

Osborne, W. S., Lintermans, M. and Williams, K. D. 1991. Distribution and conservation status of the endangered Pink-tailed Legless Lizard *(Aprasia parapulchella)* (Kluge). Research Report 5. ACT Parks and Conservation Service, Canberra.

Osborne, W. S. and McKergow, F. V. C. 1993. Distribution, population density and habitat of the Pink-tailed Legless Lizard *(Aprasia parapulchella)* in Canberra Nature Park. Technical Report No. 3. ACT Parks and Conservation Service, Canberra.

Patchell, F. C. and Shine, R. 1986. Food habits and reproductive biology of the Australian legless lizards (Pygopodidae). *Copeia* **1986**: 30-39.

Pettit, N. E., Froend, R. H. and Ladd, P. G. 1995. Grazing in remnant woodland vegetation: changes in species composition and life form groups. *Journal of Vegetation Science* **6**: 121-130.

Pough, F. H. and Gans, C. 1982. The Vocabulary of Reptilian Thermoregulation. In: *Biology of the Reptilia* (C. Gans (ed)) pp. 17-23. New York: Academic Press.

Purvis, A., Gittleman, J. L., Cowlishaw, G. and Mace, G. M. 2000. Predicting extinction risk in declining species. *Proceedings: Biological Sciences* **267**: 1947-1952.

Rankin, P. R. 1976. A note on the possible diversionary defence mechanism in the worm lizard *Aprasia parapulchella* Kluge. *Herpetofauna* **8**: 18-19.

Riley, J., Stimson, A. F. and Winch, J. M. 1985. A review of Squamata ovipositing in ant and termite nests. *Herpetological Review* **16**: 38-43.

Robertson, P. and Heard, G. W. 2008. Report on field surveys for the Pink-tailed Worm Lizard *(Aprasia parapulchella)* in the Bendigo region, central Victoria: distributiion, habitat, associations and population attributes. Report prepared for Department of Sustainability and Environment. Wildife Profiles Pty Ltd, Heidelberg, Victoria.

Robinson, W. A. 1996. Ant communities in the grasslands of the Australian Capital Territory and the role of ants in the ecology of the pink-tailed legless lizard, *Aprasia parapulchella*. Masters of Applied Sciences Thesis. University of Canberra. Canberra.

Rummery, C., Shine, R., Houston, D. L. and Thompson, M. B. 1995. Thermal biology of the Australian forest dragon, *Hypsilurus spinipes* (Agamidae). *Copeia* **1994**: 818-827.

Sass, S., Watson, D. and Wilson, A. 2008. The reptile fauna of the upper Billabong Creek catchment area, southern New South Wales. *Herpetofauna* **38**: 41-50.

Schoener, T. W. 1979. Inferring the properties of predation and other injury-producing agents from injury frequency. *Ecology* **60**: 1110-1115.

Tinkle, D. W. and Ballinger, R. E. 1972. *Sceloporus undulatus*: a study of the intraspecific comparative demography of a lizard. *Ecology* **53**: 570-584.

Velásquez-Múnera, E., Ortiz-Reyes, A., Páez, V. and Guzmán-Restrepo, G. E. 2008. Oviposition of Stenorrhina degenhardti (Serpentes: Colubridae) in a nest of Acromyrmex octospinosus (Hymenoptera: Formicidae). *Revista Actualidades Biológicas* **30**: 193-193.

Wainer, J., Robertson, P. and Yen, A. in prep. Diet of the threatened Mallee Worm-Lizard (*Aprasia aurita*) and the Pink-nosed Worm-Lizard (*Aprasia inaurita*) in north-western Victoria.

Wilson, S. and Swan, G. 2008. *A Complete Guide to Reptiles of Australia. 2nd Edition.* New Holland Publishers (Australia), Sydney.